PB-228 525

FIELD THERMAL POLLUTION STUDY, PRELIMINARY REPORT. OHIO RIVER, WHEELING, WEST VIRGINIA AREA

Federal Water Pollution Control
Administration
Wheeling, West Virginia

January 1968

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PB 228 525

FIELD THERMAL POLLUTION STUDY

PRELIMINARY REPORT

OHIO RIVER

WHEELING, WEST VIRGINIA AREA

Work Document No. 12

This document has been prepared to record a specific water pollution control activity carried out to date in the furtherance of the water pollution control program being developed in the Ohio River Basin. The information contained herein will serve as a ready reference to aid in the planning and development of the program in the Basin, for appropriate in-service training of participating personnel, and facilitating program activities with other cooperating groups.

Questions or comments relative to this material should be directed to:

Laboratory Services Section
Wheeling Field Station
Ohio River Basin Project
Wheeling, West Virginia

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UNITED STATES DEPARTMENT OF THE INTERIOR
FEDERAL WATER POLLUTION CONTROL ADMINISTRATION
OHIO BASIN REGION

January 1968

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I. INTRODUCTION

Purpose

The purpose of this document is to present the results of a preliminary study of the effects of thermal pollution on the Ohio River near Wheeling, West Virginia. The study was designed to develop procedures for aiding in the determination of the effects of major heat loads to the Ohio River and to define the resultant mixing zones. The reach around mile point 76-78 was chosen as a study area since this contains the Cardinal Station (1,230 megawatts) which is one of the largest steam electric plants in the country plus the Tidd Station (222 megawatts).

Thermal pollution represents one of the growing threats to maintenance of good quality water. This usually occurs below major industries such as steel mills and steam-electric generating plants. Thermal pollution from most steam electric generating plants usually exceeds thermal pollution from industrial outfalls.

The Ohio Valley around Wheeling, West Virginia, is becoming an electric power center because of the great coal reserves that exist in Ohio and West Virginia. Most of these steam-electric generating facilities are located near the coal reserves so they are commonly called mine-mouth electric generating stations.

On the Ohio River from mile point 54 to mile point 112 there are presently ten steam-electric generating plants producing a total of 4,050 megawatts of power or enough electricity to supply a city of four million people. In one hour these plants can produce a heat load to the river of over 24 billion B.t.u's or enough energy to heat about 300,000 average size homes.

Acknowledgments

No formal contact was made with the Ohio Power Company, which operates both plants. An unofficial tour of the Cardinal Station, however, was made in the spring of 1967.

River discharge information was obtained from the Pike Island Locks and Dam operated by the U. S. Army Corps of Engineers, Pittsburgh District.

The field work was performed by various members of the Field Operations Section, Planning and Evaluation Section, and the Laboratory Services Section of the Wheeling Field Station.

II. SUMMARY

Findings

1. A satisfactory technique was developed for measuring river temperature increases and thermal loads at suspected areas.
2. The river water increased at the highest point about 15° F., but the overall average of any cross-section only increased about 1.5° F.
3. The Ohio River during moderate flows of 44,000 to 52,000 cfs did not indicate any thermal pollution problem directly below steam electric generating plants producing 1,452 megawatts during the fall season.
4. Considering these flows and the cool fall season in which this preliminary study was made, much higher thermal loads might be experienced during normal low flow periods in late summer.
5. During the conditions of this study, indications are that a one-half mile mixing zone is present. Below the mixing zone, the overall average water temperature begins to decrease to the natural level.
6. Considerably more thermal pollution work must be performed to determine thermal loads at varying air temperatures and river flows with respect to different size steam-electric generating plants.

Recommendations

1. It is recommended that a resurvey be conducted in the same area of the Ohio River during summer time flows of 5,000 to 10,000 cfs to determine the thermal loads at high air temperatures of 75-95° F.
2. Surveys are also needed at other thermal electric plants to determine thermal loads and mixing zones with respect to different electric generating capacities.

III. SURVEY DESCRIPTION

Location

The study area consisted of the reach of Ohio River from mile point 76 to mile point 78. Two power stations are located in this reach; namely, the Tidd plant at mile point 76.2 and Cardinal plant at mile point 76.5. They are located on the west bank of the Ohio River about 10 miles south of Steubenville, Ohio, near the town of Brilliant, Ohio. Upstream, the Weirton Steel Company and the Wheeling Steel Company have large steel mills in the Steubenville, Ohio - Weirton, West Virginia, area.

Survey Stations

The river is about 1200 feet wide in this reach with a maximum depth of about 30 feet. A nine foot navigational channel is maintained in this part of the Ohio River. The two power plants in the study area are located about eight miles above the Pike Island Dam.

To adequately assess the thermal pollution in this area, a reference station was established upstream of the Tidd plant as shown in Figure 1. Downstream stations were chosen to show the effects of the thermal loads discharged by the plants.

The sampling points used for the Tidd-Cardinal plant area for each of three surveys were as follows:

1. October 2, 1967

   Mile Point 76.3 Reference Point

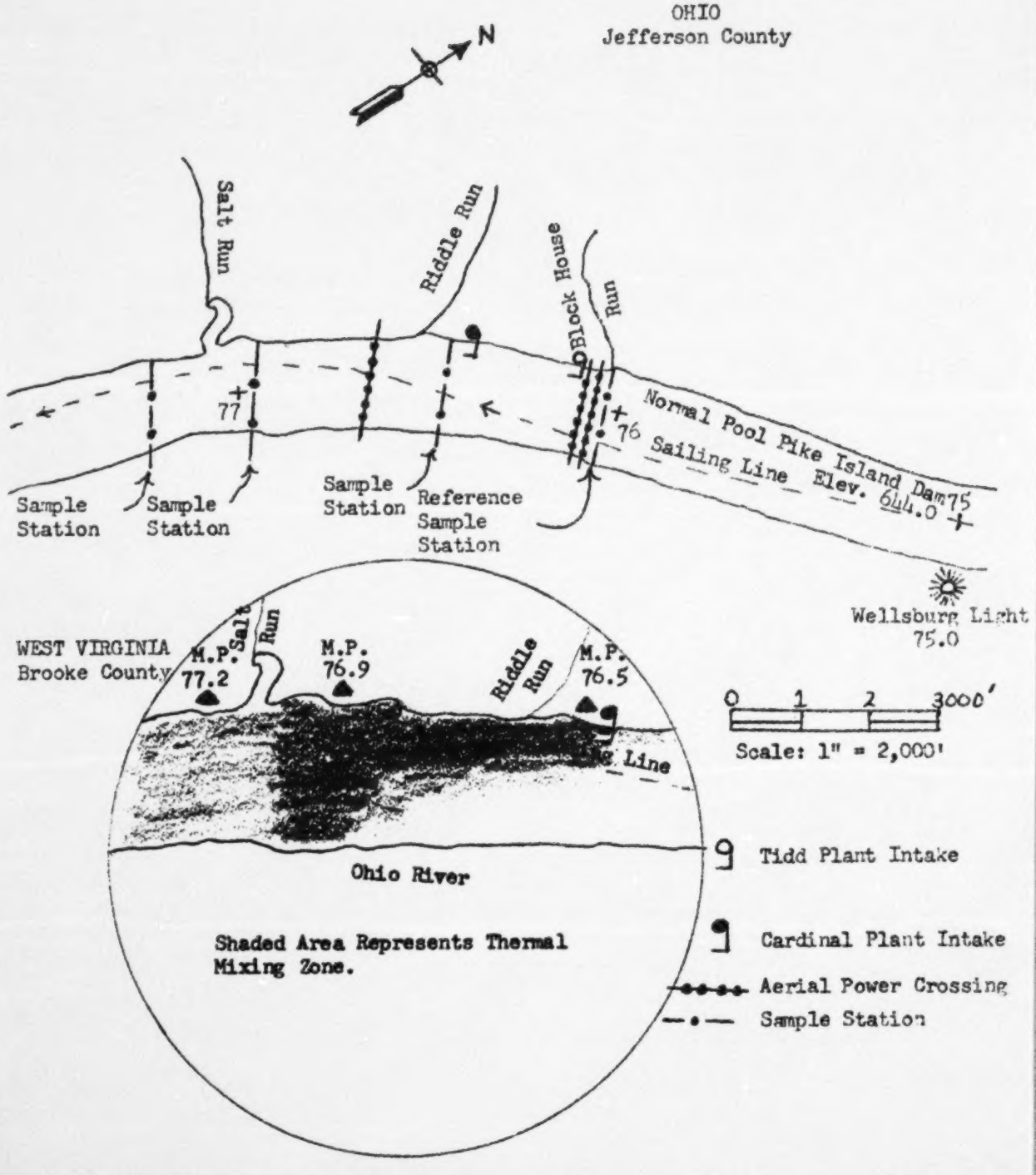
   Mile Point 76.5 Cardinal Plant outfall

2. October 3, 1967

   Mile Point 76.3 Reference Point

   Mile Point 76.5 Cardinal Plant outfall

Figure 1
Ohio River Mile Point 75 to Mile Point 76
Thermal Pollution Studies



Mile Point 76.9 Downstream of outfall

Mile Point 77.2 Second downstream point of outfall

3. October 23, 1967

Mile Point 76.3 Reference Point

Mile Point 76.5 Cardinal plant outfall

Mile Point 76.9 Downstream of outfall

Mile Point 77.2 Second downstream point of outfall

Temperature measurements were taken using Yellow Springs Instruments, model no. 51, Dissolved Oxygen Meters utilizing a thermistor probe on a 50-foot cable. All measurements were made from the Wheeling Field Station, 24-foot cabin cruiser anchored in position at various points across the river. Temperature measurements were taken at two to four foot increments from the surface to bottom of the river to determine thermal stratification. A cross-sectional area of the river was determined from a recording depth sounder chart and a Corps of Engineers navigational chart.

Electric Power Plant Information

The Tidd Electric Power Station has a rated capacity of 222 megawatts and the Cardinal Power Station has a rated capacity of 1,230 megawatts or about five times larger than the Tidd Station. No thermal pollution problems are known to have existed when only the Tidd Plant operated in this area. The Cardinal plant started limited power output in 1966 and went to full capacity in August 1967. It is interesting to note that although hydro-electric and nuclear power plants are being built at a rapid rate, fossile fuel power plants are still expected to double in the next 10 years.

The Cardinal Power Station consists of two 615,000 KW high pressure (3,500 psi) steam generating turbines. The entire plant cost about

$125 million. It is jointly owned by the Ohio Power Company and the Buckeye Power Company with the Ohio Power Company having operating responsibility. About 1 1/2 billion gallons per day or 2300 cfs of river cooling water is required for once through condensor cooling. This represents about 75% of the seven consecutive day, once in 10 year low flow of the Ohio River at this point.

IV. THERMAL POLLUTION

Background

Temperature alterations of streams, rivers and lakes have become an increasing industrial pollution syndrome. There are many interacting factors that do not readily show if thermal discharges have a deleterious effect upon stream purification capacity. Heated discharges can adversely affect bodies of water for other water uses. It can affect aquatic life by lowering the dissolved oxygen below acceptable levels and thermal shocks can cause fish kills.

The enthalpy balance of a polluted stream, along with the upstream reference point, defines the downstream temperature field. Any source of thermal effluent that alters the normal downstream condition can be considered as an abnormal enthalpy modification. The cooling water discharge from condensers of steam-electric generating plants is a good example of this situation.

It was reported by B. C. Dysart and P. A. Krenkel in the 20th Purdue Industrial Waste Conference in 1965 that for each kilowatt hour (kwh) generated in a modern, coal fired, steam electric generating plant, approximately 6000 B.t.u.'s must be dissipated by means of cooling water. The cooling water will often increase as much as 24° F. above normal conditions.

To adequately define thermal pollution is difficult since time of year and even time of day makes a difference. Changes in water temperature cause gases such as carbon dioxide to change their selective toxicity toward fish. At 1° C., the CO_2 concentration that is lethal to carp is 120 mg/l, while at 30° C. it is lethel betweel 55 to 60 mg/l. Fish in general depend on temperature changes to act as a signal for such things as migration, spawning, and distribution. This upset may change the life cycle of fishes.

As the temperature of water increases, the solubility of dissolved oxygen decreases. The decreased oxygen level reduces the natural assimilation capacity of the stream for normal oxidation. Oxygen consumption by aquatic vertebrates doubles for every 10° C. rise in stream temperature, so that the problems of increased water temperatures are compounded. Different species of fish have different thermal death points (t.d.p.). For example, a flathead minnow acclimated to 10° C. has a t.d.p. of 28.2° C., whereas at 20° C., it has a t.d.p. of 31.7° C. A point is reached where both the acclimated level and the increased thermal death point are nearly the same.

There are a few benefits of increased water temperature. Although heated zones eliminate some varieties of fish, an extended period of feeding can occur in these waters during cold months. Certain species stop eating entirely when stream temperature drops to less than 54° F. Reoxygenation from phytoplankton photosynthesis increased with temperature over a restricted range, if other factors such as light intensity and nutrient levels are held constant.

Thermal Conditions

Before the regular survey of October 2, 3 and 23, 1967, initial study runs were made to develop the testing plan to best describe the thermal conditions. Because of river mixing by towboats, it was found that four foot depth increments could be used for most stratification measurements. Also, the number of points measured across the river could be from four to five at most stations.

Overall, thermal conditions are determined by establishing a reference point above the thermal discharge, finding the thermal zone at the source, determining the mixing zone below the source and finding the point where the

thermal load diminishes. All of this should be accomplished in as short a time period as possible.

For this study all temperature data are recorded in degrees Fahrenheit. The reference point was established at mile point 76.3 just above the Tidd Power Station. The cross-sectional temperature values at the referance point were rather uniform.

Air temperatures for the study periods were considered with respect to water temperature, but since each survey was usually completed within six hours, this was not a problem. Large bodies of water usually exhibit very little temperature fluctuations within part of a day, regardless of air temperature ranges.

In Table 1 below, the average reference river temperature and air temperature ranges are presented for each survey period. The overall reference temperature changes between each sample period is believed to be more influenced by upstream reservoir discharges, than by the air temperature ranges during the study periods.

TABLE 1
Study Periods - Background Temperatures

Date	River Reference Temperature (M.P. 76.3)	Air Temperature Ranges
October 2, 1967	67.1° F.	59-75° F.
October 3, 1967	63.8	64-78
October 23, 1967	57.2	45-68

Dissolved oxygen was determined at various cross-sections, but difference ranged more with respect to depth than temperature. No detailed dissolved oxygen account is given since values always exceeded 5.0 mg/l. In most cases,

dissolved oxygen represented about 75% of saturation.

It was assumed from information obtained from other studies that river velocities were rather uniform from bank to bank and from surface to bottom for this reach of river since it is relatively straight without obstructions.

The incremental temperature increases, the average temperature increases and the total thermal loads are tabulated in Table 2. A typical cross-section profile is also shown in Figure 2.

The incremental temperature increases in the cross-section for the various sampling periods range from 0 to 14.1° F. across the river. The incremental temperature increases from top to bottom are much smaller. The range from the top 12-foot section to the lower 12-foot section varies from 0 to 3.2° F. The temperature increases near the Ohio shore are higher since the power stations are located on that side of the river. The individual temperature increases depict a wedge shape pattern both at the surface and lower levels below the outfalls. Strong cross currents were also observed which were caused by the tremendous power plant discharges of about one million gallons of water per minute. It should be noted that the warmest stream temperature recorded at any spot during the survey was 80° F., which is below the recommended water quality standard of 93° F.

The average temperature increase for a cross-section was determined from the weighted average of temperature increases with respect to the percentage of cross-section area to the whole area. The highest average temperature increase for any of the cross-sections was 1.44° F. at mile point 76.9 about one-half mile below the Cardinal Power Station outfall. It appears that this one-half mile section represents the mixing zone at the study flows.

TABLE 2
OHIO RIVER THERMAL INCREASE
(Reference Point, Mile Point 76.3)

Incremental Temperature Increase

Mile Point	Date	Flow (cfs)	Depth (feet)	(W. Va.) 25' 5%	350' 30% of Flow	350' 30% of Flow	350' 30% of Flow	20' 5% (Ohio)	Average Temperature Increase °F	Total Thermal Load In Btu/Hr. (x 10^6)
76.5	10-2-67	44,000	0-12	0.5	0.5	0.5	0.9	12.9	1.24	12,300
			12-24	0.5	0.6	0.5	0.8	---		
	10-3-67	48,000	0-12	---	---	0.3	5.9	9.7	1.12	12,100
			12-24	---	---	---	---	---		
	10-23-67	52,000	0-12	---	0.2	---	2.2	14.1	0.98	11,500
			12-24	---	---	---	1.8	---		
76.9	10-2-67	44,000	0-12	0.5	0.6	0.6	2.7	13.0	1.27	12,600
			12-24	0.5	0.8	0.6	0.9	---		
	10-3-67	48,000	0-12	---	0.5	4.3	2.9	---	1.31	14,100
			12-24	---	---	1.1	---	---		
	10-23-67	52,000	0-12	0.1	---	4.3	2.3	---	1.44	16,800
			12-24	---	---	1.8	1.1	0.7		
77.2	10-3-67	48,000	0-12	0.4	2.2	2.2	1.9	---	1.10	11,900
			12-24	---	0.4	0.5	---	---		
	10-23-67	52,000	0-12			1.6	(Only a mid-stream measurement			
			12-24			1.5	was made on this date.)			

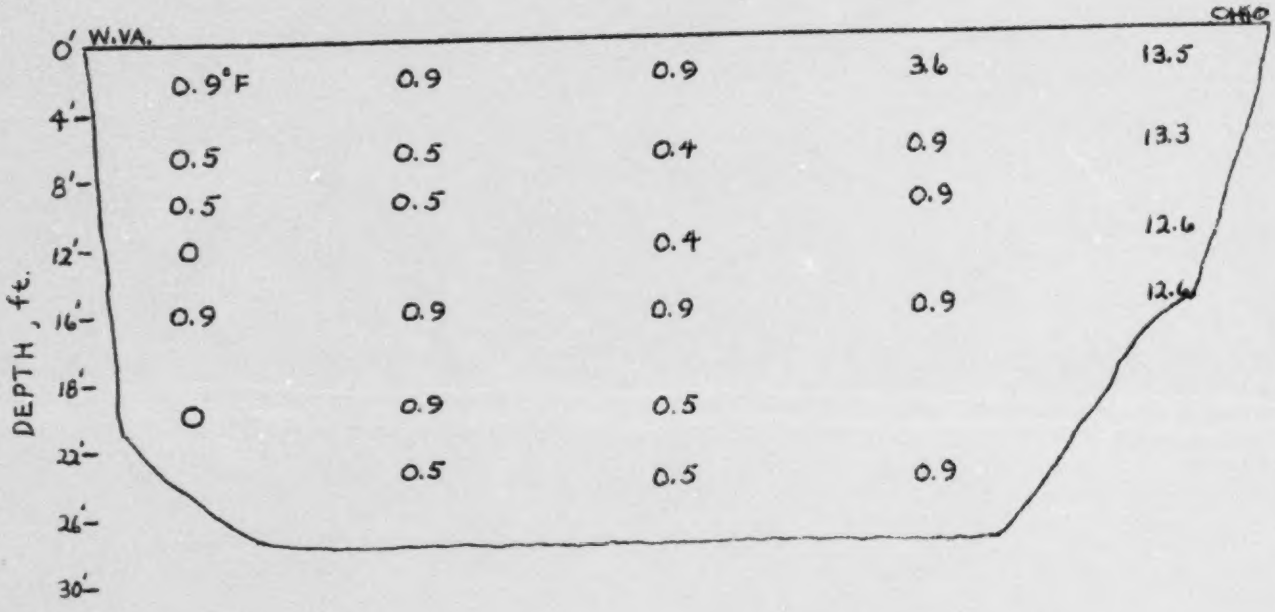
--- No change

Figure 2

Typical Temperature Increase Profile
Ohio River, Mile Point 76.9
October 2, 1967

Flow: 44,000 cfs

Δ °F Over Reference Temperature of 67.1° F



(APPROXIMATELY 1200 ft. WIDE)

The total thermal load was determined in B.t.u.'s with respect to the average temperature increase times the flow in pounds per hour. The maximum thermal load observed was 16.8 billion B.t.u.'s. This is about 93% higher than an overall theoretical amount that might be expected from plants of their capacities. It has been learned that the Cardinal Plant may be discharging at a higher temperature than the original design, but during this study this had little effect since the river temperature was considerably below the proposed water quality standard. The flows during this study period were moderate, ranging from 44,000 to 52,000 cfs. Considering these flows and the fall season in which the study was made, much higher thermal loads might be experienced during lower flows in late summer.

Thermal pollution studies in general need to be continued to determine the mixing zone at various flow and air temperatures with respect to different size electric power stations. It is recommended that studies similar to this plan be conducted to fully evaluate the situation at various locations in the upper Ohio River basin.